DARK ENERGY
SURVEY

Calibration and PreCam

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for the DES Calibrations and PreCam Survey Teams

DES Collaboration Meeting
ICG, Portsmouth

1 July 2011

Basic DES Observing Strategy

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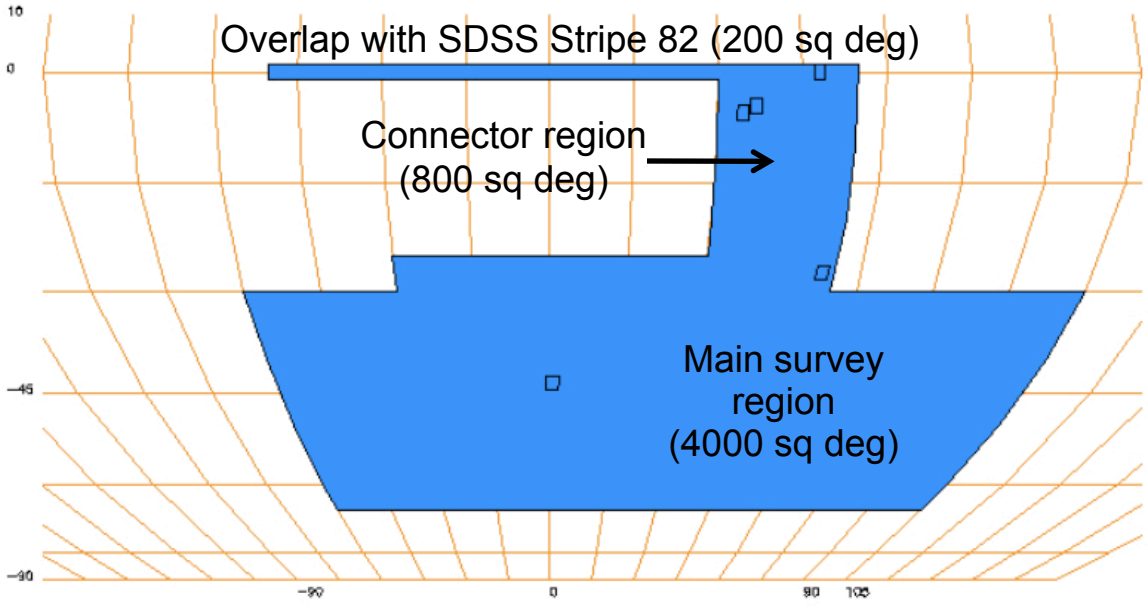
Observing Strategy

- 100 sec exposures (nominally)
- 2 filters per pointing (typically)
  - *gr* in dark time
  - *izy* in bright time
- Multiple overlapping tilings (layers) to optimize photometric calibrations
- 2 survey tilings/filter/year
- Photometric Requirements (5-year)
  - All-sky internal: 2% rms (Goal: 1% rms)
  - Absolute Color: 0.5% (*g-r*, *r-i*, *i-z*); 1% (*z-y*)
  - Absolute Flux: 0.5% in *i*-band (relative to BD+17 4708)

Survey Area

Credit: J. Annis



Total Area: 5000 sq deg

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DES Photometric Calibration Plan in 6 Points

1. Instrumental Calibration (Nightly & Periodic): Create biases, dome flats, spectrophotometric response maps, etc.

2. Photometric Monitoring: Monitor sky with 10μm All-Sky Cloud Camera.

3. PreCam Survey: Create a network of calibrated DES *grizy* standard stars.

4. Nightly and Intermediate Calibrations: Observe standard star fields with DECam and apply the results.

5. Global Relative Calibrations: Use the extensive overlaps between exposures over multiple tilings to tie together the DES photometry onto an internally consistent system across the entire DES footprint.

6. Global Absolute Calibrations: Use DECam observations of spectro-photometric standards in combination with measurements of the full DECam system response map to tie the DES photometry onto an AB magnitude system.

1. Instrumental Calibration:
The DECal System Response Maps

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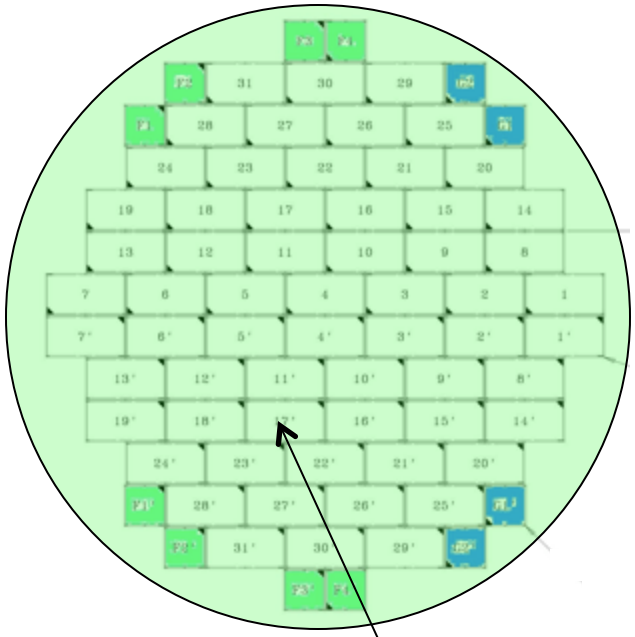

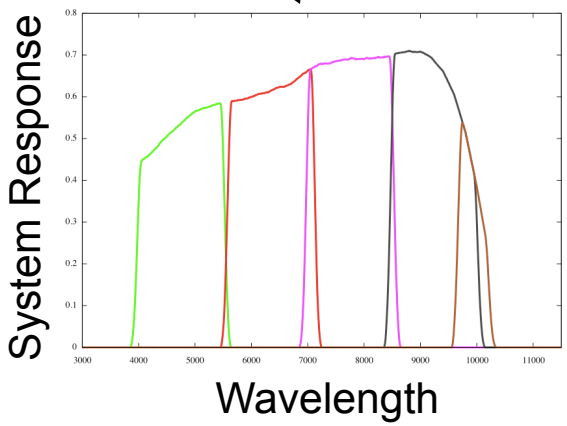

Spectrophotometric System Response Map

(See Jennifer Marshall's DES Review talk; DES-doc#5504)

- It is expected that the shape of the system response will be a function of position on the focal plane.
- Therefore, the system response map from the spectrophotometric calibration system will be important for Global Absolute Calibration, catalog and image co-adds, enhanced calibration of specific classes of astronomical objects, and system performance tracking over time.
- This would typically be a once-a-month calibration, taking several hours to measure all 5 DES filters.

2. Photometric Monitoring:
The 10 micron All-Sky Camera

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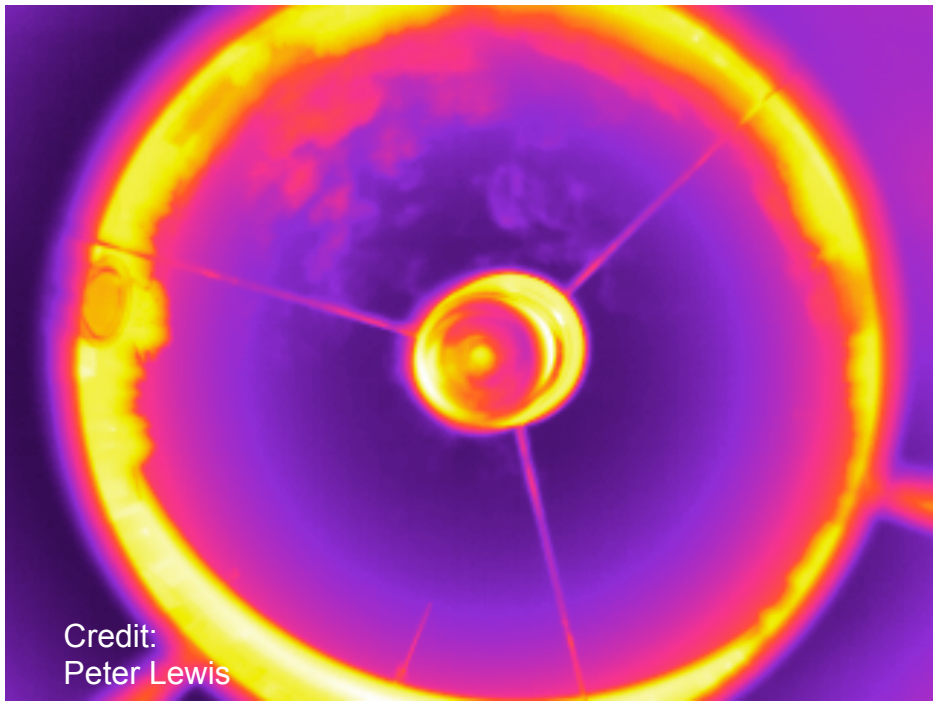
RASICAM

- "Radiometric All-Sky Infrared CAMera"
- Built by SLAC (Peter Lewis, Rafe Schindler)
- Web interface for observers
- Photometricity flags passed to each exposures FITS header via SISPI for use by DESDM
  - Nightly calibrations
  - Global relative calibrations
- Installed at CTIO in June 2011



RASICAM image: light cirrus

3. The PreCam Survey:
What is it?

PreCam Survey: a quick, bright *grizy* survey in the DES footprint using a 4kx4k camera composed of DECam CCDs – the "PreCam" – built by Argonne (Kyler Kuehn, Steve Kuhlmann) and mounted on the University of Michigan Dept. of Astronomy's Curtis-Schmidt Telescope at CTIO.

Originally conceived by Darren DePoy (April 2008).

Observations took place in Aug/Sep 2010 and Nov 2010 - Jan 2011.

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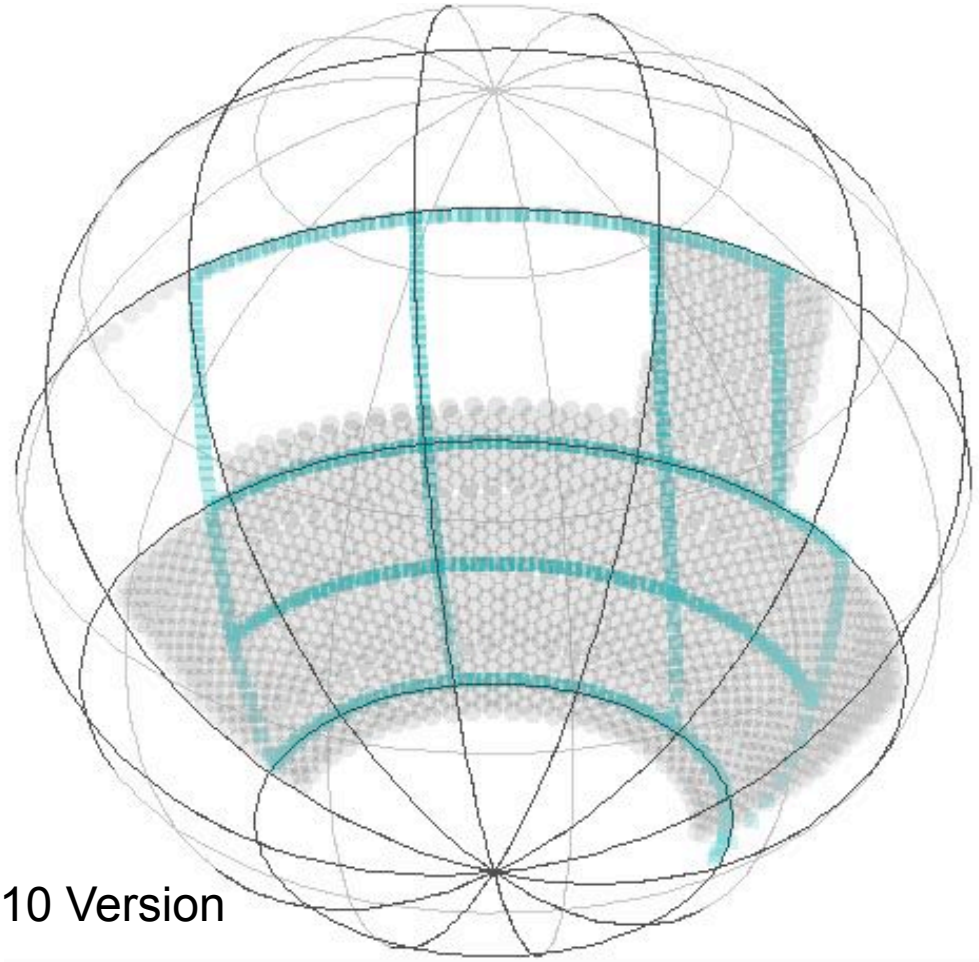
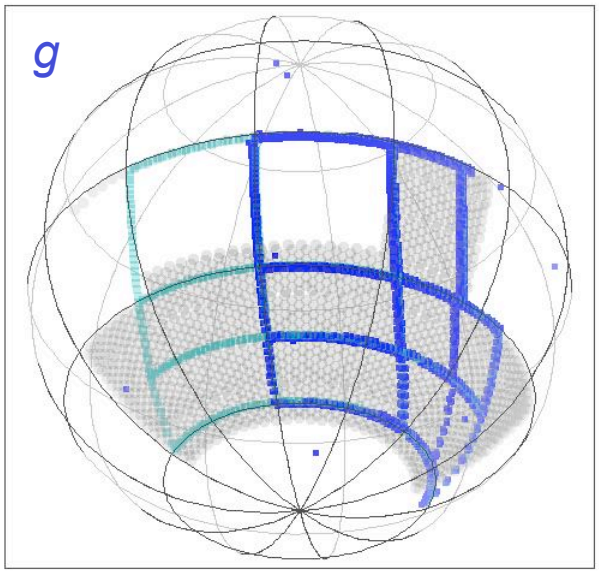
3. The PreCam Survey:
The Survey Strategy as Planned

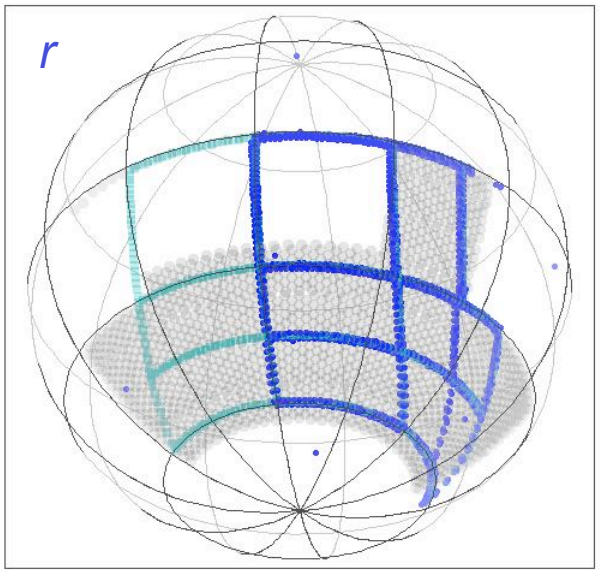
- ≈500 sq deg (10% DES area)
  - PreCam FOV 1.6°x1.6°
- ≈30° grid pattern
- Cover grid 10x in each filter (*g*, *r*, *i*, *z*, *y*)

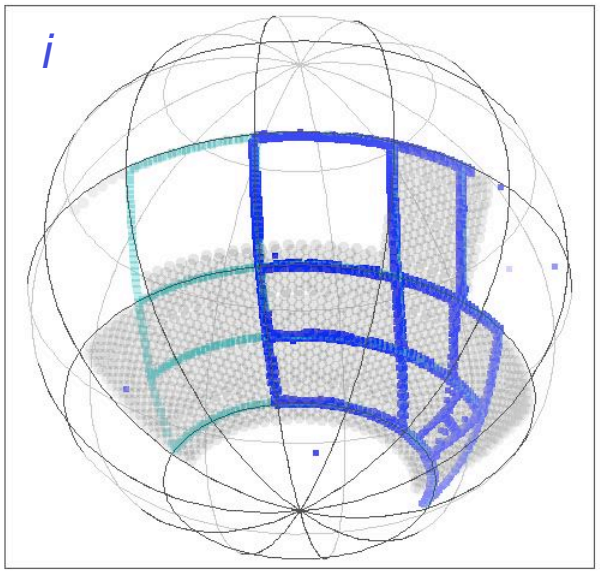


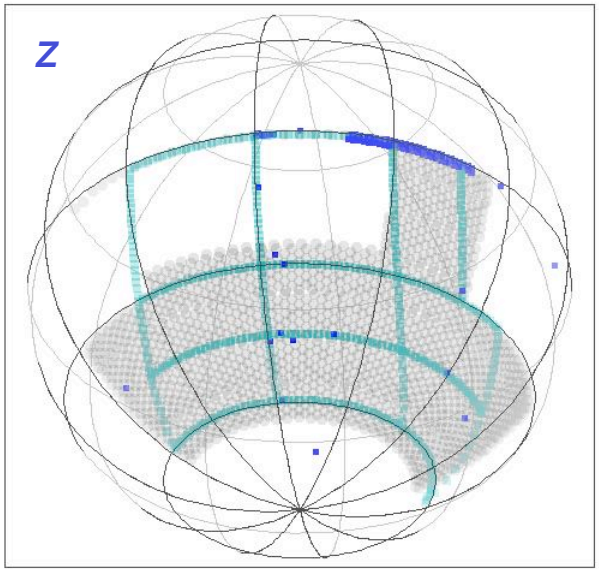
Aug 2010 Version

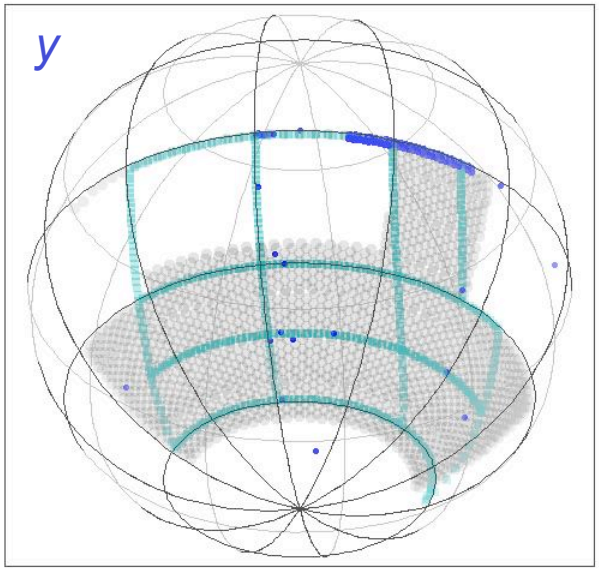
3. The PreCam Survey:
Actual PreCam Coverage as of Jan 20, 2011











≈ 10x in Stripe 82 in each filter (*g,r,i,z,y*)

≈ 6x over rest of grid in each filter (*g,r,i*)

3. The PreCam Survey:
Data Processing
(DES-Brazil and FNAL/ANL Efforts)

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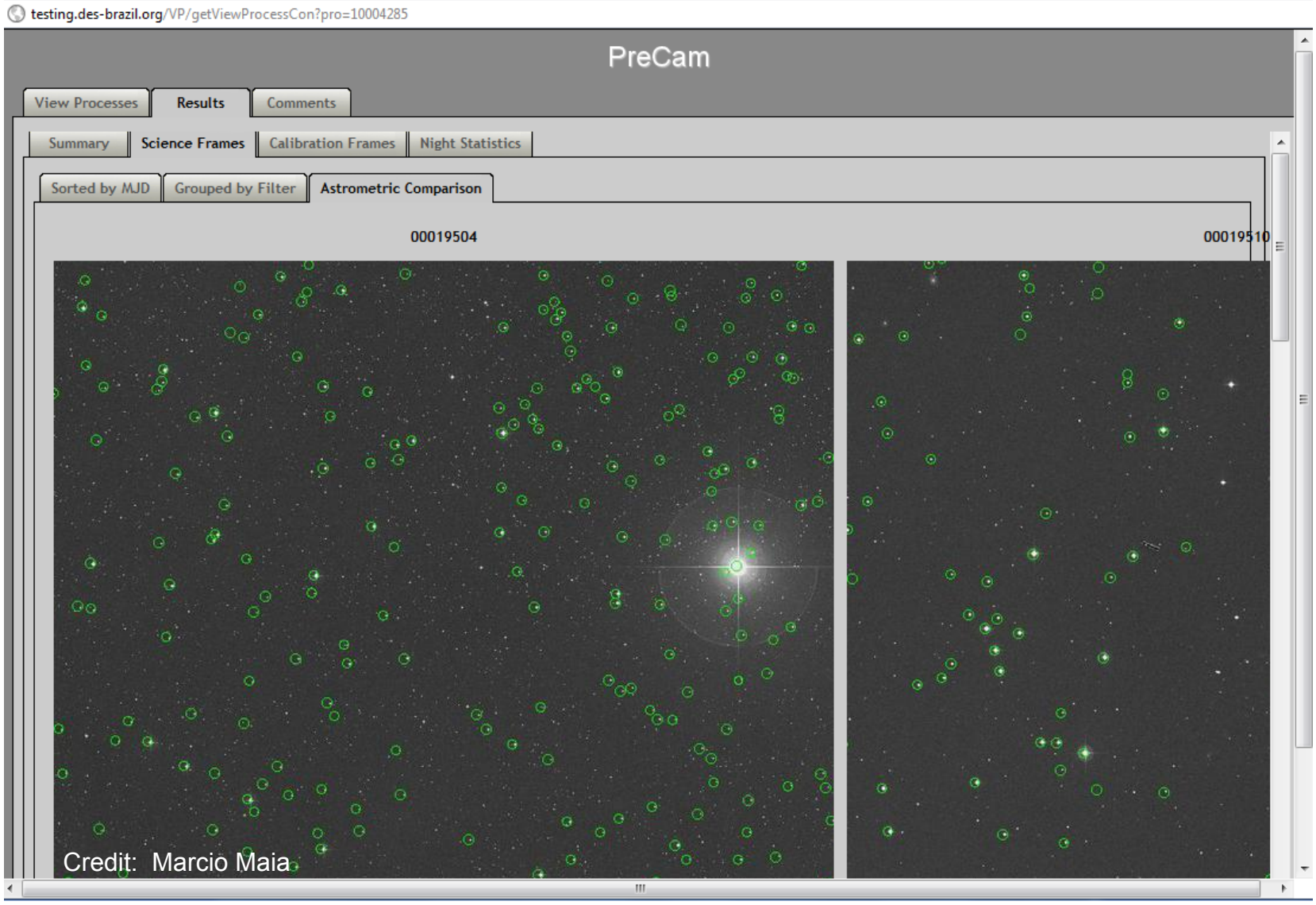
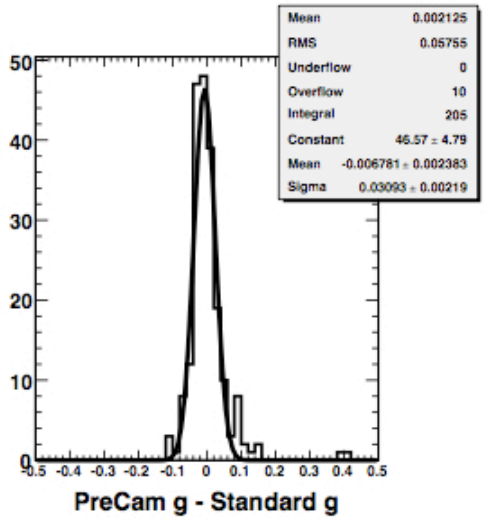
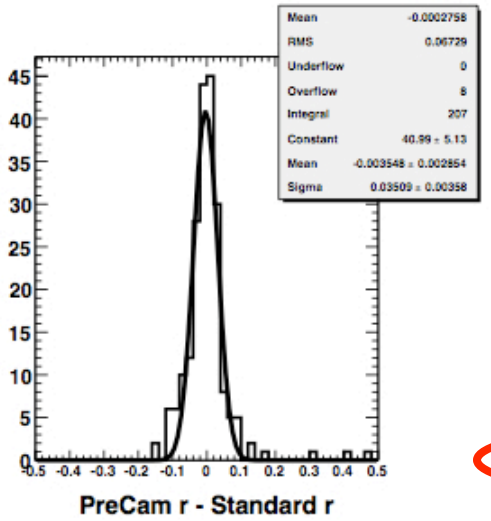


3. The PreCam Survey:
Some Initial Photometry Results

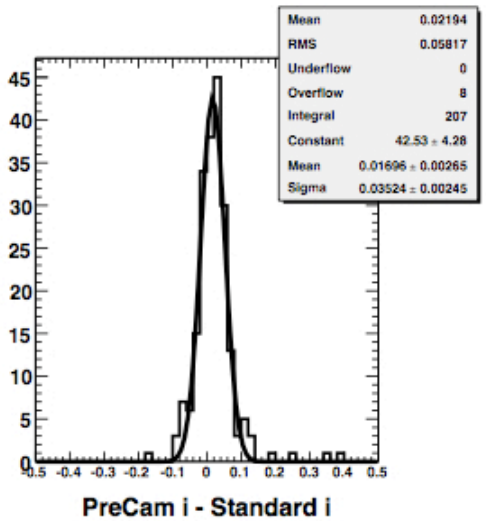
DARK ENERGY SURVEY



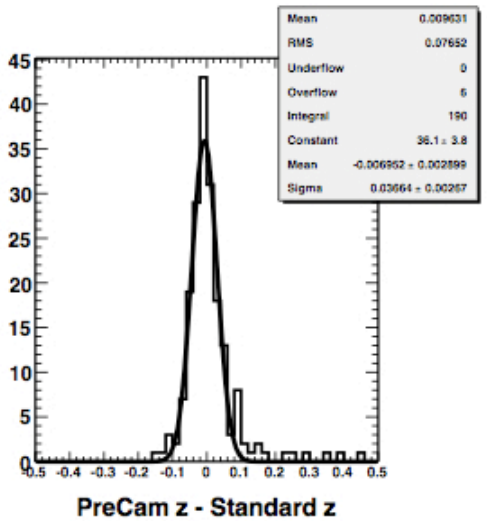
PreCam g - Standard g



PreCam r - Standard r



PreCam i - Standard i



PreCam z - Standard z

2011-01-13 initial processing completed

Catalogs matched to USNO, SDSS, and Southern u'g'r'i'z' standard star fields
10's to 100's of stars matched...

~2% errors brighter than 16th mag
2-4% errors for no mag cut
5+% errors in a few circumstances

Systematic offset (0.07 mag) for some SDSS fields (20110107?)

Credit: Steve Kuhlmann, Hal Spinka, Kyler Kuehn

3. The PreCam Survey:
Some Results on SDSS-DES Color Terms

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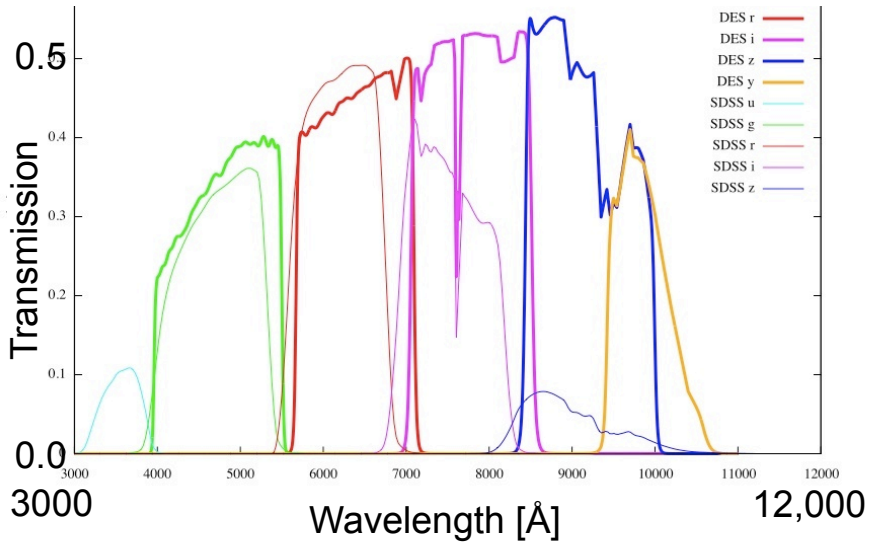
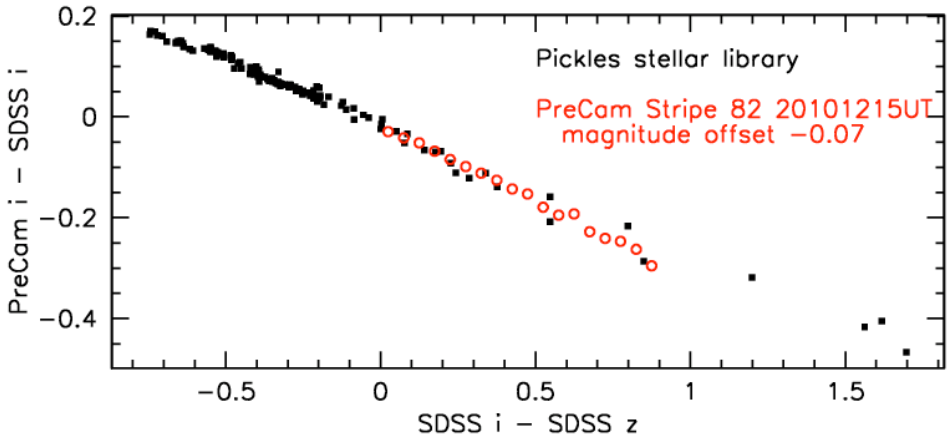
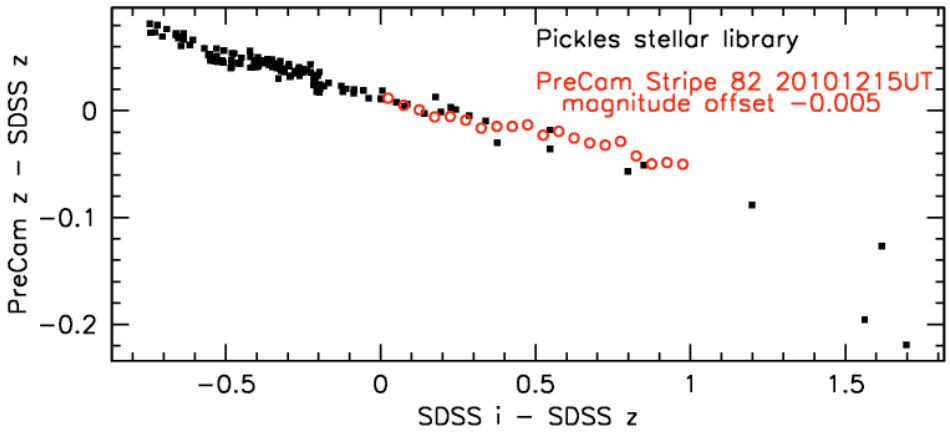
SDSS & DES Response Curves



Synthetic & Observed PreCam Color Terms





Credit: Huan Lin

4. Nightly/Intermediate Calibrations: Standard Stars for DES

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Photometric Equation: $m_{inst} - m_{std} = a_n + b_n \times (stdColor - stdColor_0) + kX$

SDSS Stripe 82

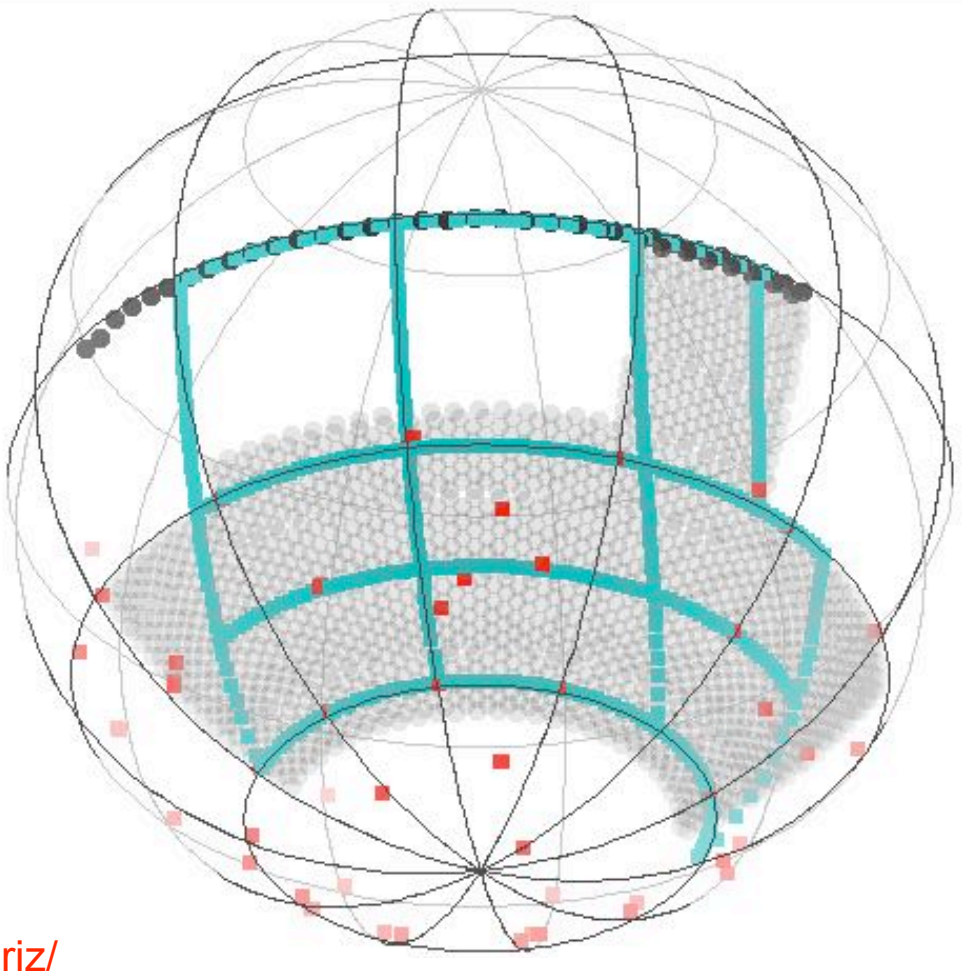
- ~10^6 tertiary *ugriz* standards
- *r* = 14.5-21
- ~4000 per sq deg
- 2.5° x 100° area
- See Ivezic et al. (2007)

PreCam

- DES *grizy*
- *r* = 13.2-17.8 (goal)
- 500 sq deg
- ≈200 per sq deg

Southern u'g'r'i'z' Standards

- Sixty 13.5'x13.5' fields
- *r* = 9-18
- Typically tens per field
- See http://www-star.fnal.gov/Southern_ugriz/



4. Global Relative Calibrations: The Need and The Strategy

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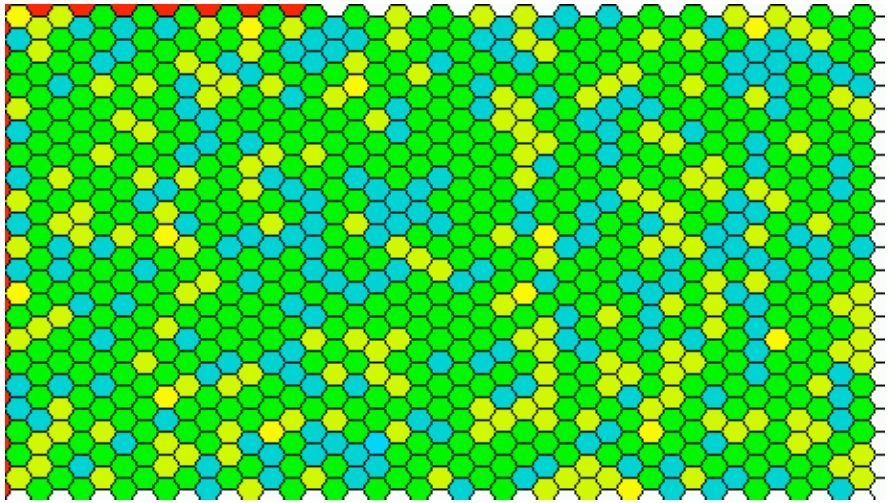
We want to remove field-to-field zeropoint offsets to achieve a uniformly "flat" all-sky relative calibration of the full DES survey, but…

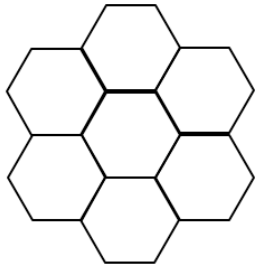
DES will not always observe under truly photometric conditions…

…and, even under photometric conditions, zeropoints can vary by 1-2% rms field-to-field.

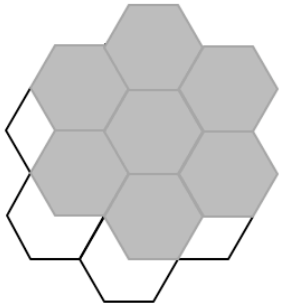


scaling bar is –0.20 mags to +0.20 mags

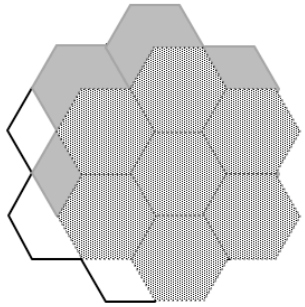
1 tiling



2 tilings



3 tilings



The solution: multiple tilings of the survey area, with large offsets between tilings.

We cover the sky twice per year per filter. It takes ~ 1700 hexes to tile the whole survey area.

Credit: Jim Annis

5. Global Relative Calibrations: The Role of PreCam Data

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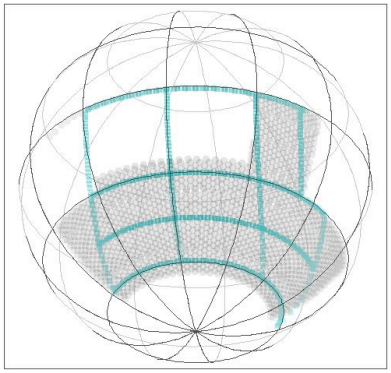
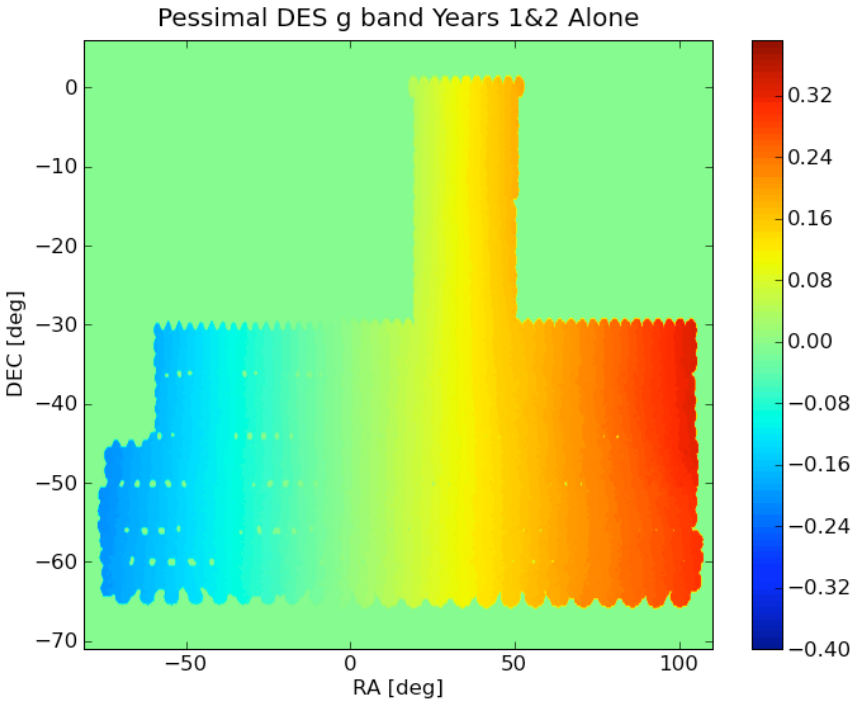
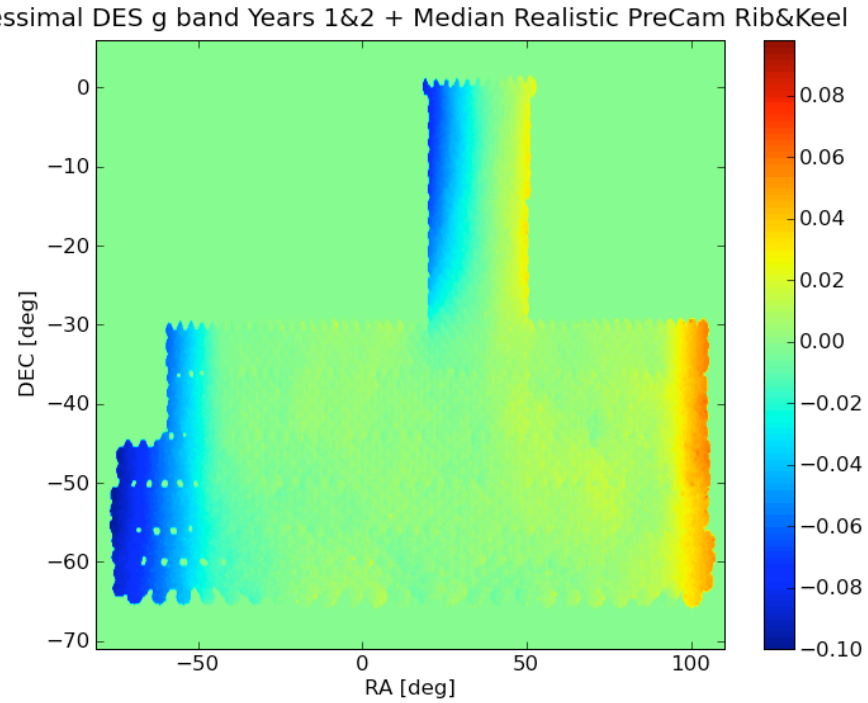
- A rigid framework onto which to tie the DES photometry
- PreCam helps DES achieve its global relative calibrations requirements sooner (and also helps protect against certain pathological calibration failures).







6. Global Absolute Calibrations: Basic Method

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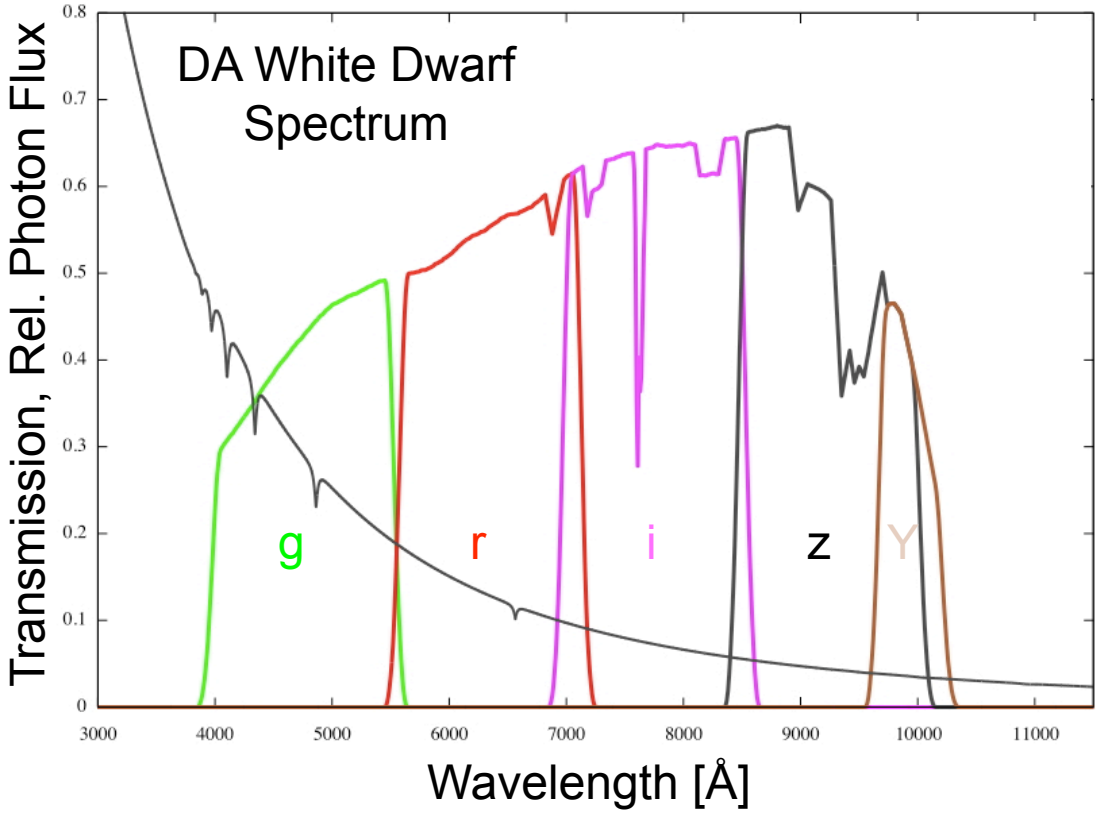
- Compare the synthetic magnitudes to the measured magnitudes of one or more spectrophotometric standard stars observed by the DECam.

- The differences are the zeropoint offsets needed to tie the DES mags to an absolute flux in physical units (e.g., ergs s^{-1} cm^{-2} $Å^{-1}$).

- Absolute calibration requires accurately measured total system response for each filter passband as well as one or more well calibrated spectrophotometric standard stars.



Near Term Plans

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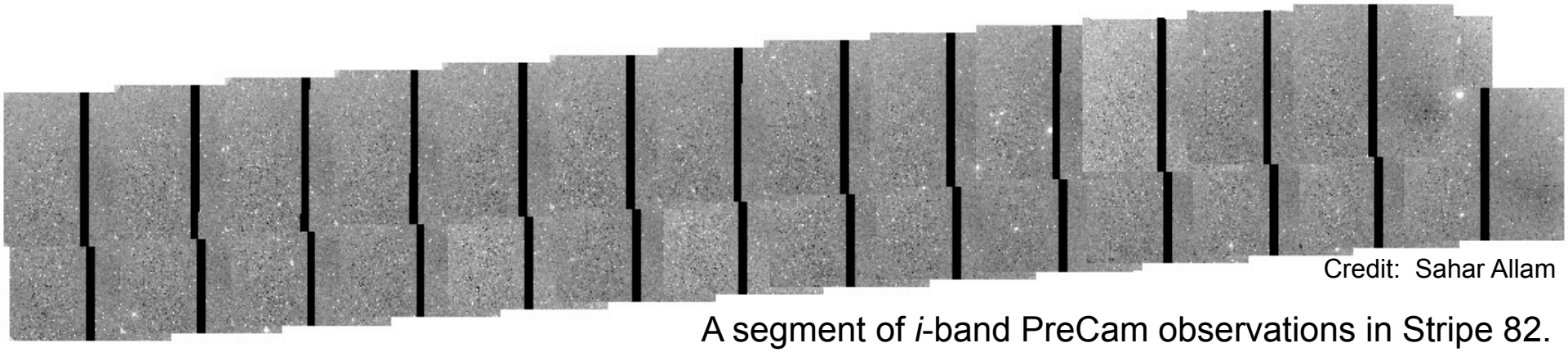
1. Analyze PreCam data and prepare for a PreCam Review to request a second observing season for late-2012/early-2013.
2. Finish Global Calibrations Module and Photometric Standards Module (including Star Flat measurements) for DES commissioning and beyond.
3. Integrate DECal (spectrophotometric response) system outputs into calibration framework, including the “George” DESDM module.
4. Plan for DECam commissioning and DES mini-survey
5. Much, much more…



Credit: Sahar Allam

A segment of *i*-band PreCam observations in Stripe 82.

PreCam Observers: Commissioning & Operations

Sahar Allam
Jim Annis
Eduardo Balbinot
Joe Bernstein
Tomasz Biesiadzinski
David Burke
Melissa Butner
Julio Camargo
Darren DePoy +TAMU group
Brian Gerke
Rick Kessler
Kyler Kuehn
Steve Kuhlmann
Wolfgang Lorenzon
Marcio Maia
Leandro Martelli
Brian Nord
Ricardo Ogando
John Peoples
Dominik Rastawicki
Joerg Retzlaff
Michael Schubnell
J. Allyn Smith
Adam Sypniewski
Greg Tarle
Douglas Tucker
Will Wester

And special thanks to:

Oscar Saa and CTIO TelOps

Tim Abbott, Chris Smith, Alistair Walker

Pat Seitzer (PI of Curtis-Schmidt NASA program)

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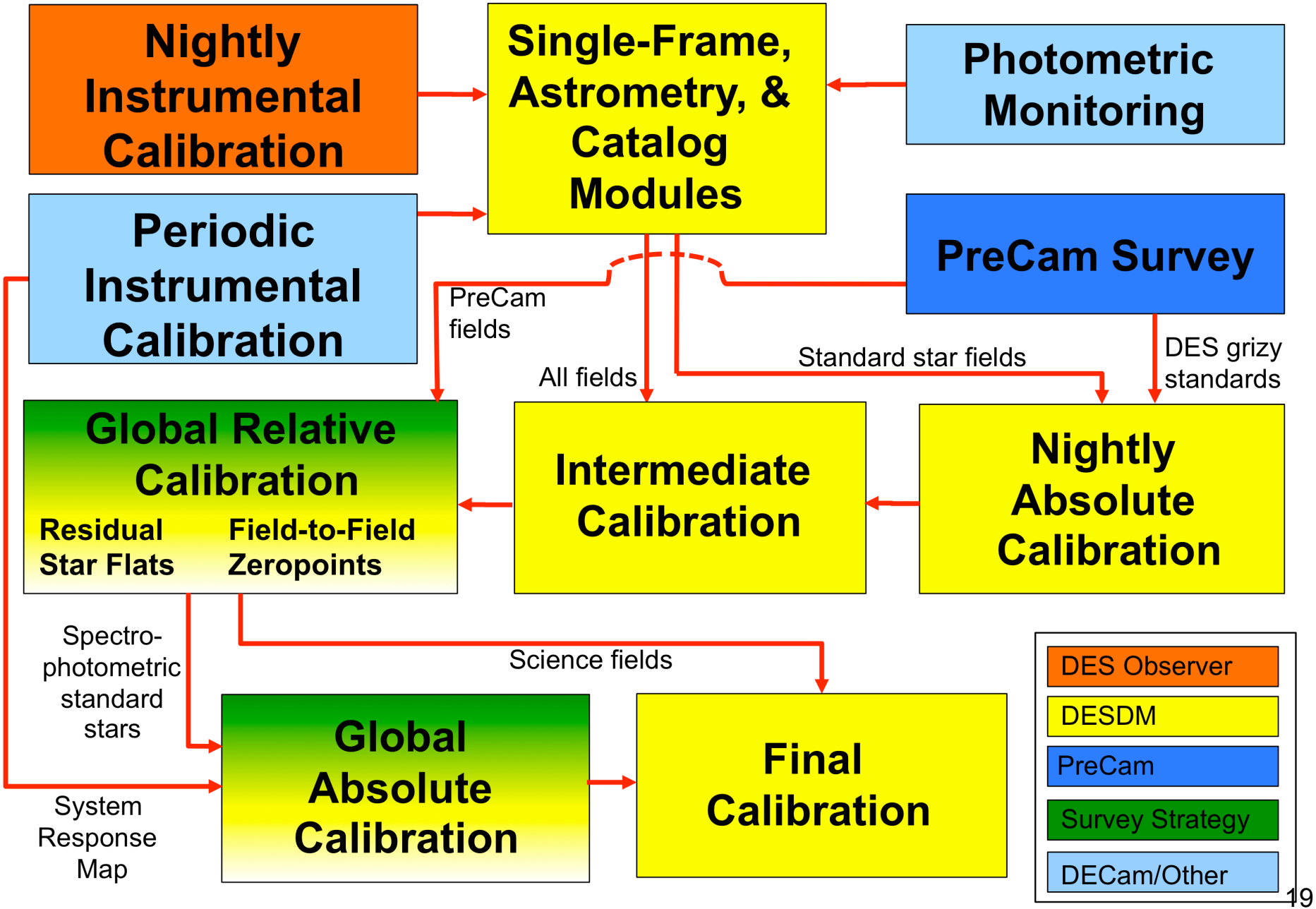
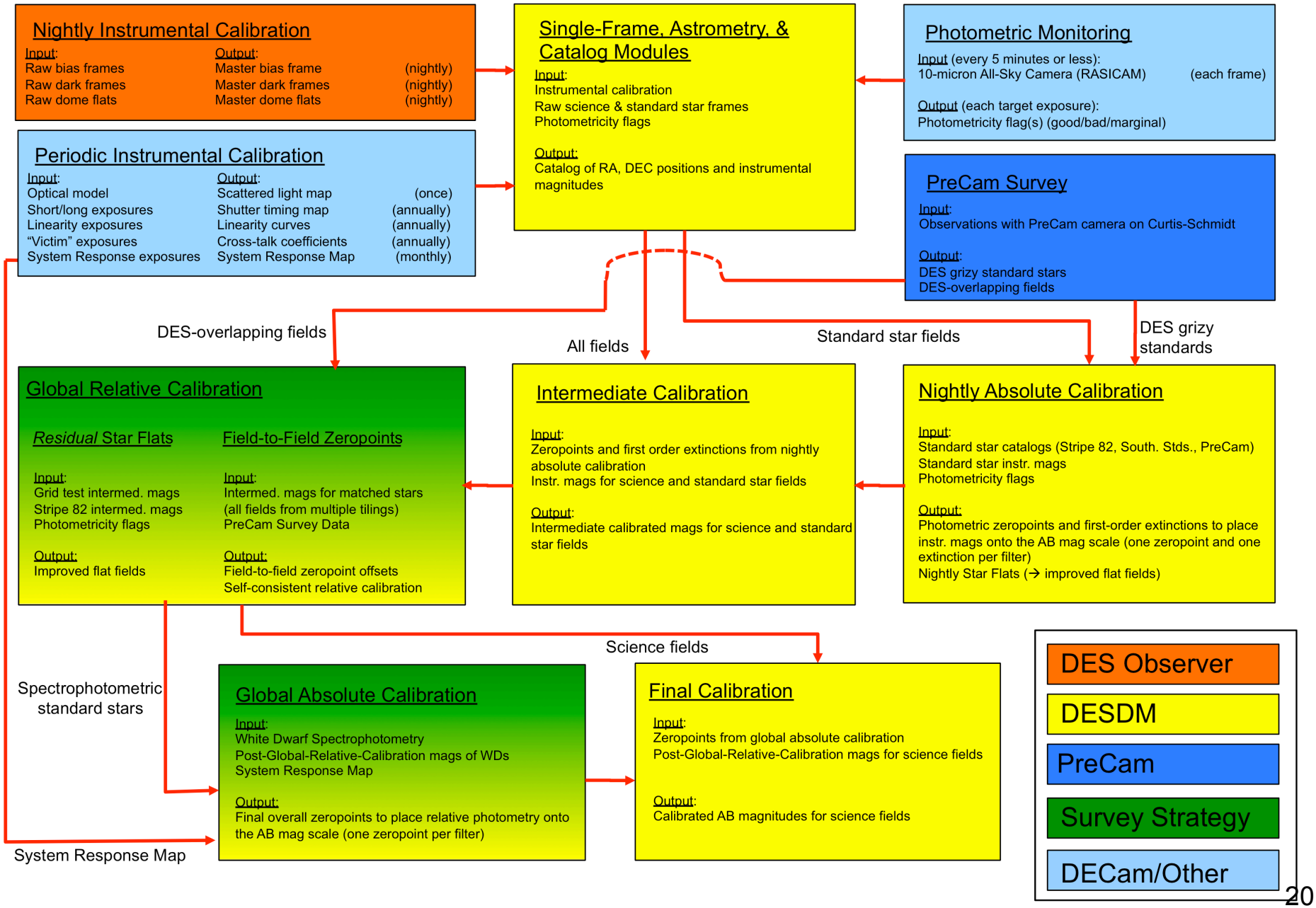
Extra Slides

DES Photometric Calibrations Flow Diagram (v4.1)



DES Photometric Calibrations Flow Diagram (v4.1)



The Curtis-Schmidt Telescope

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Credit: The Argonne Guys

- 0.9m Primary Mirror + 0.6m Corrector Plate
- PreCam-related upgrades (TAMU):
  - New secondary mirror + mount
  - New flat-field screen and LED-based dome flat field lamps
- Agreement with University of Michigan Department of Astronomy granted the PreCam Survey 100 nights between Aug 2010 and January 2011 (which includes commissioning time).

The PreCam Camera

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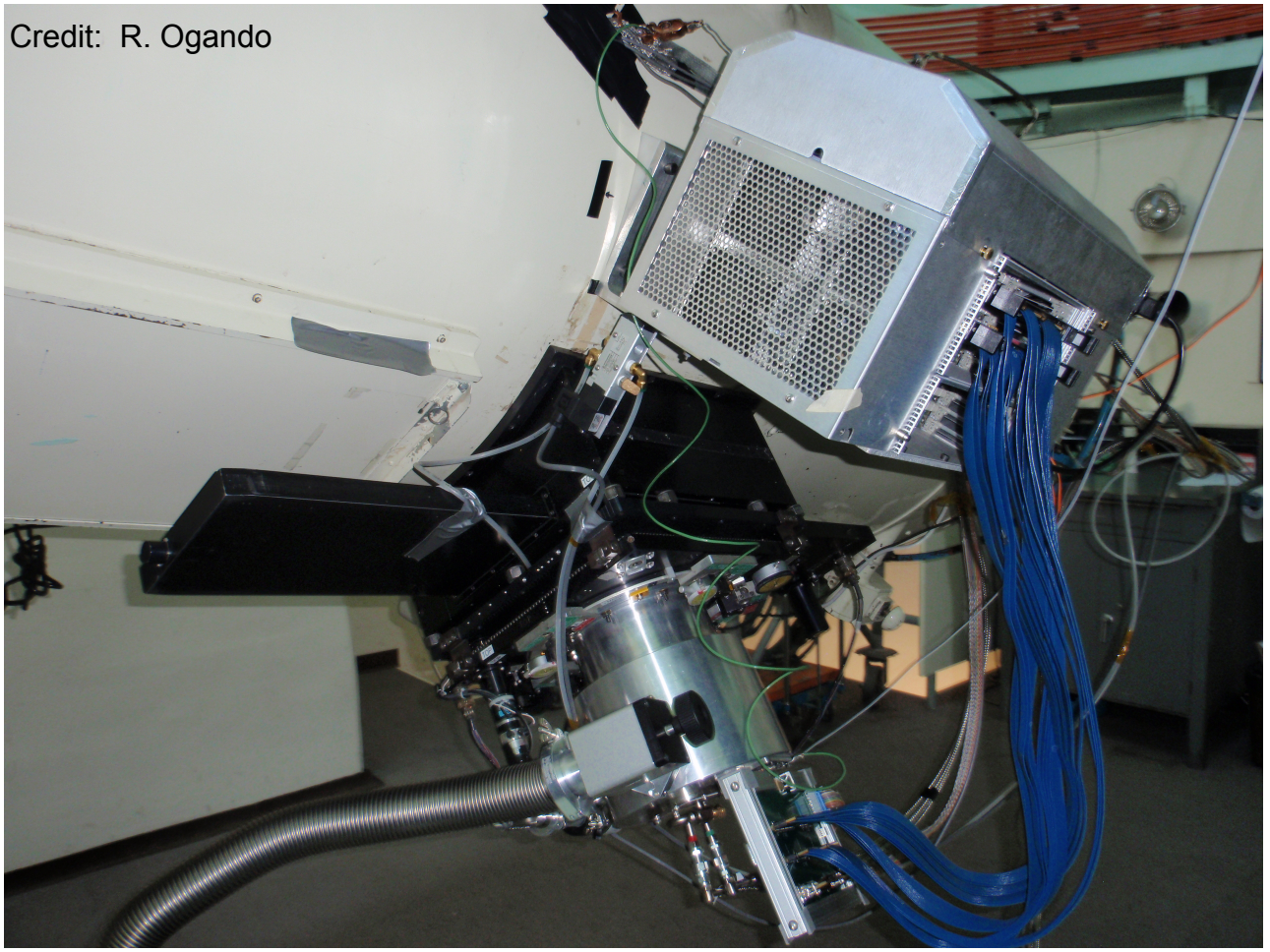
- Built by Argonne group (Kyler Kuehn, Steve Kuhlmann).
- PreCam FOV on C-S with TAMU secondary is 1.6°x1.6°.



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3. The PreCam Survey: Characteristics

- 2 DECam 2k x 4k CCDs
  - FOV of 1.6º x 1.6º (2.56 sq deg) at a pixel scale of 1.4 arcsec/pixel
- 112 scheduled nights (which included installation & commissioning)
- Goals: to act as a test-stand of DECam h/w and s/w and to obtain a sparse-but-rigid gridwork of stars in DES *grizy* photometrically calibrated to better than ~1%

Baseline PreCam Survey Point-Source Magnitude Limits (optimized to achieve S/N=50 at DES saturation + 1.5mag)

Band	Exposure time [seconds]	PreCam saturation limit	PreCam mag limit S/N=50	Number of usable stars per sq deg (SGP)
g	36	12.8	17.8	186
r	51	13.2	17.8	265
i	65	13.4	17.7	344
z	162	14.1	17.5	317
y	73	11.6	14.3	150

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Nov-Jan: The Data

- 64 nights allocated (Nov 16-Jan 20 minus Dec 24-25)
  - 1 night lost to weather
  - 2 nights lost to software meltdown on original DAQ computer
  - 2 nights lost to shutter breaking
  - 4 nights devoted to engineering due to shutter-sticking
  - 1 night lost due to venting dewar to ambient atmospheric pressure
  - 1 night lost due to problems with installing new 12-channel DAQ card
  - 2 nights devoted to end-of-run engineering tests
- 51 nights on sky (c. 80% of the 64 nights allocated)
- ~24,000 images

August-September Problems

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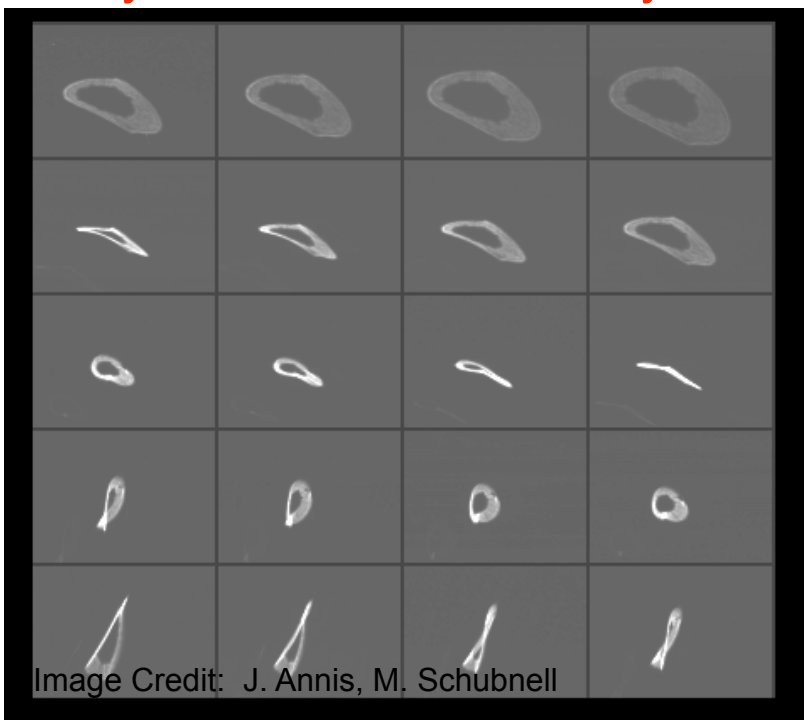
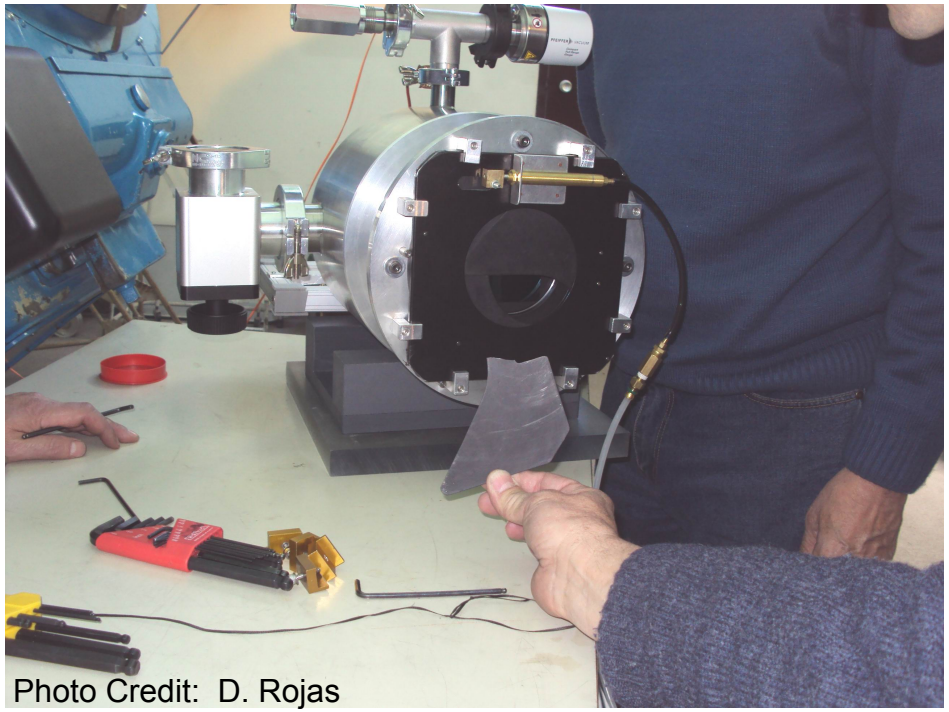
Poorly Manufactured 2ndary Mirror



Broken Shutter



FITS header problems,
(esp. w.r.t. adding RA,DEC from Curtis-Schmidt TCS)

```
SIMPLE  =                    T / conforms to FITS standard
BITPIX  =                   16 / array data type
NAXIS   =                    0 / number of array dimensions
EXTEND  =                    T
…
RA      = '25:0:0.0'         / [HH:mm:ss.ss] RA for center of this detector
DEC     = '91:0:0.0'         / [DD:mm:ss.ss] Dec for center of this detector
…
```

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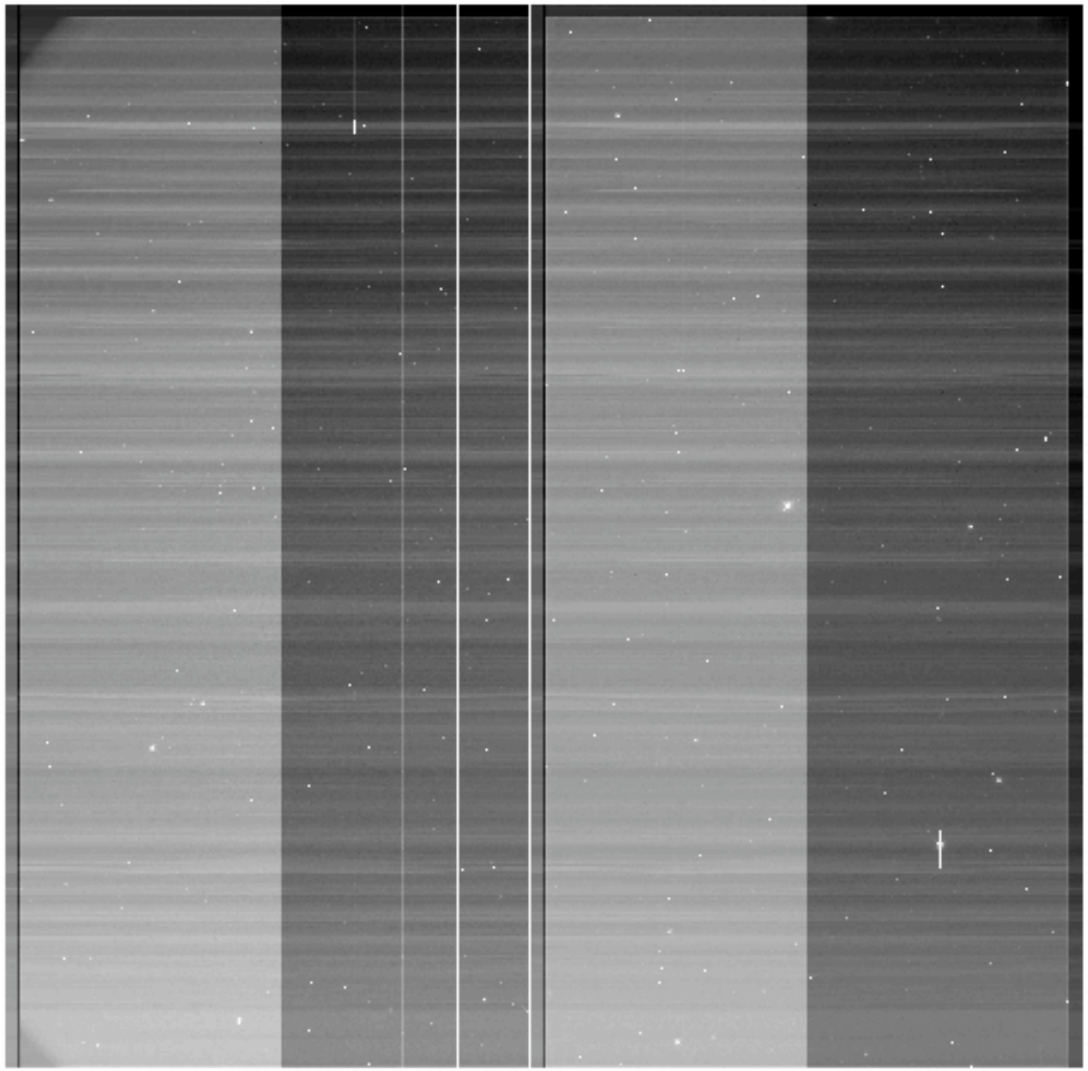
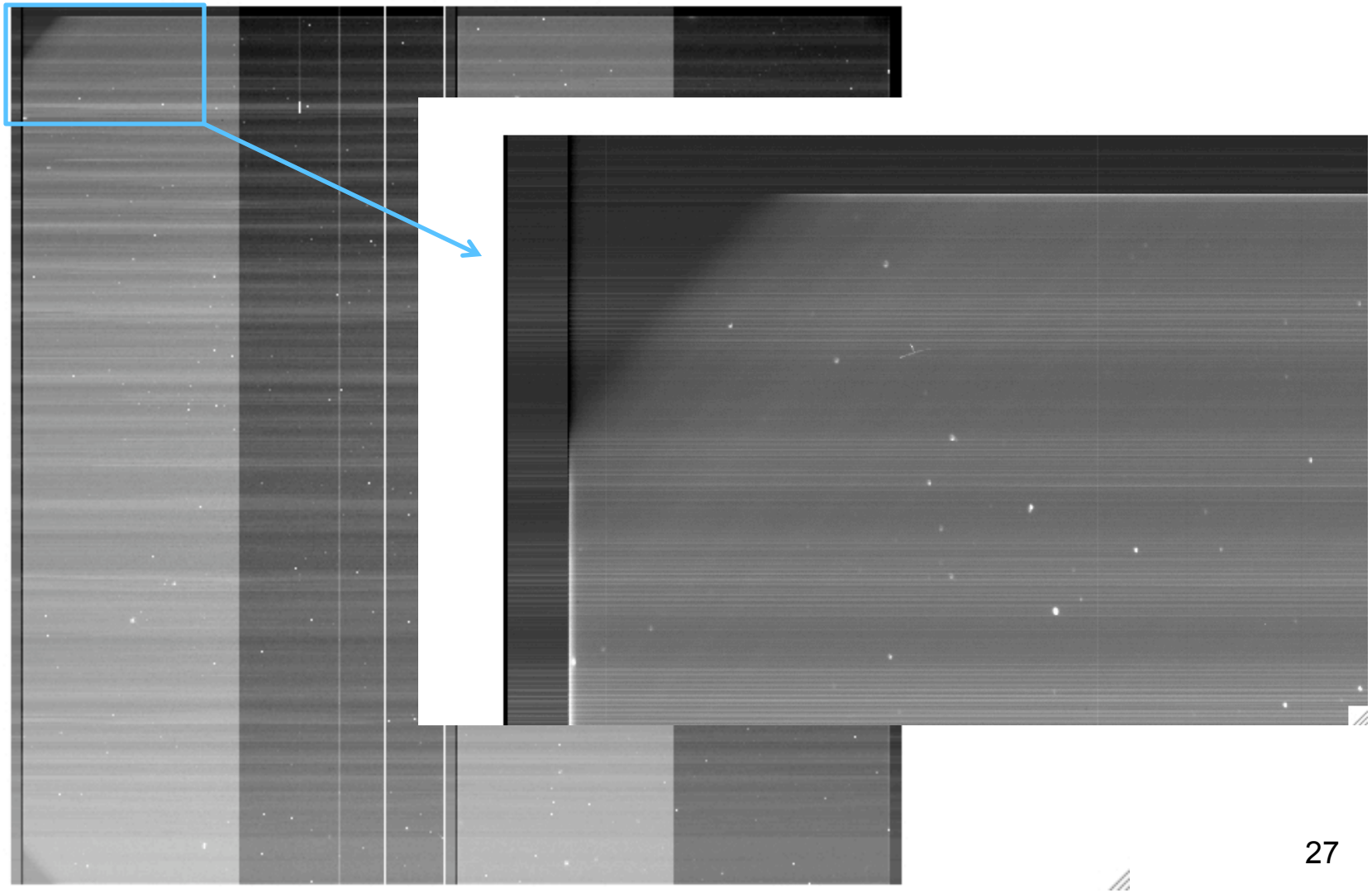
Results:
Horizontal Banding & Streaking



DARK ENERGY SURVEY

Results: Horizontal Banding & Streaking

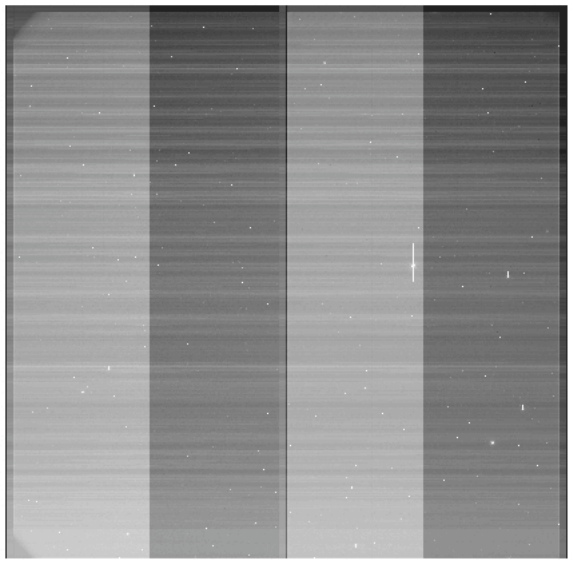


DARK ENERGY SURVEY

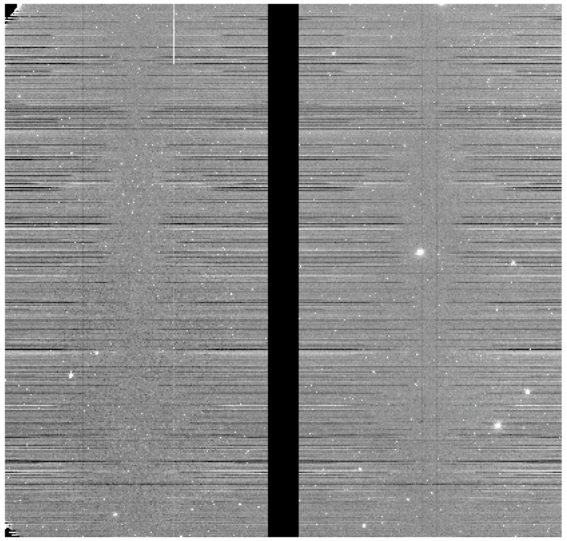
Results: Horizontal Banding & Streaking

A Pretty Bad Case of Banding and Streaking

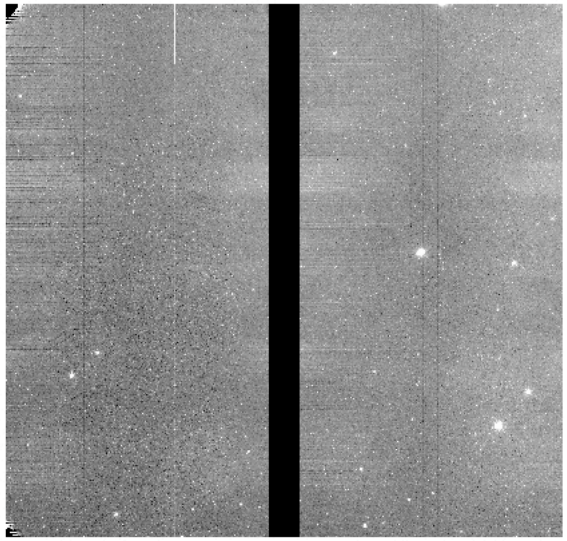
Original Image



After row-by-row overscan subtraction



After horizontal streaking correction



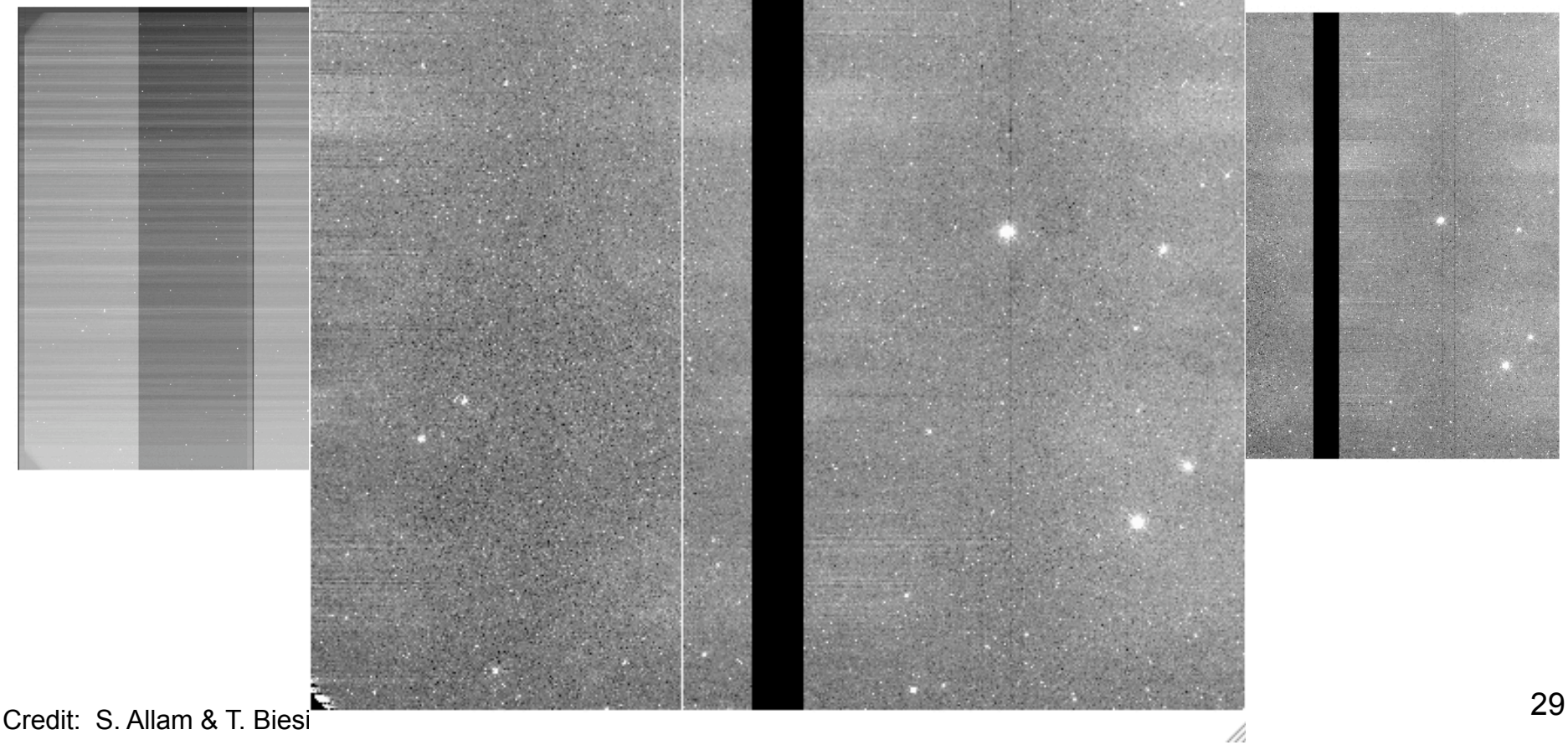
Credit: S. Allam & T. Biesiadzinski

Results:
Horizontal Banding & Streaking

DARK ENERGY SURVEY

Original Im

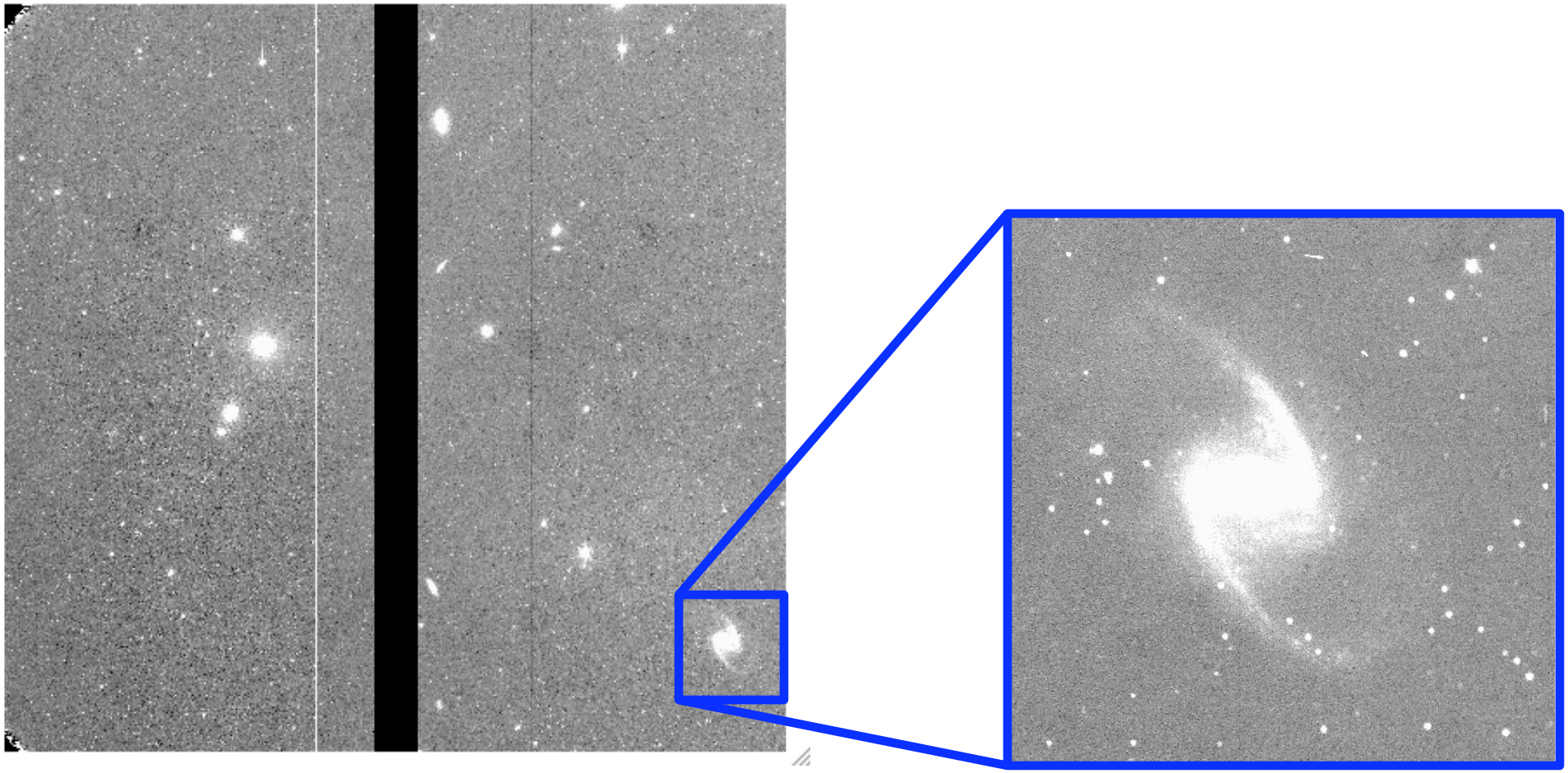
er horizontal
king correction



Credit: S. Allam & T. Biesi

A Processed *i*-band PreCam Image from Jan 13

DARK ENERGY SURVEY



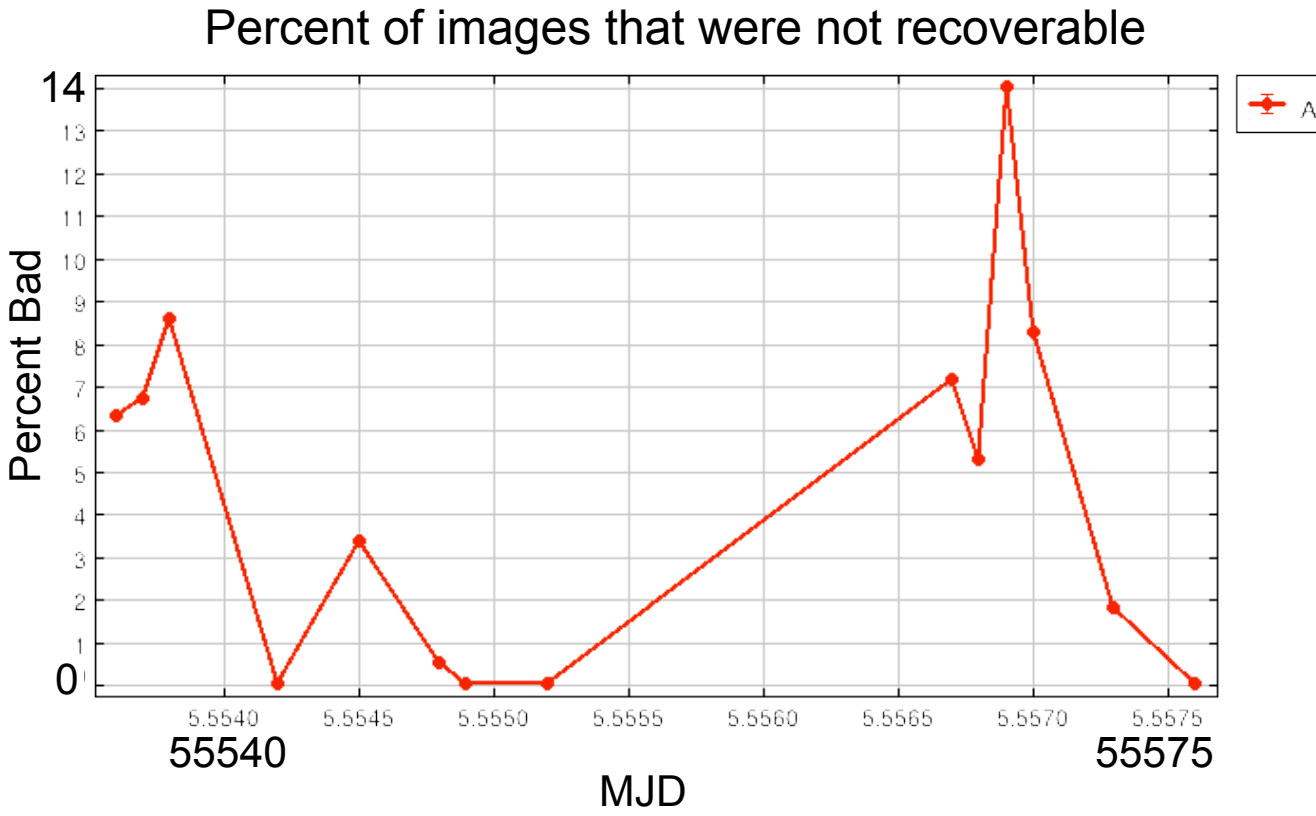
1.6 deg

Results: Horizontal Banding & Streaking

DARK ENERGY SURVEY

- Horizontal banding & streaking affect ≈40% of the raw PreCam standard star field and science target images.

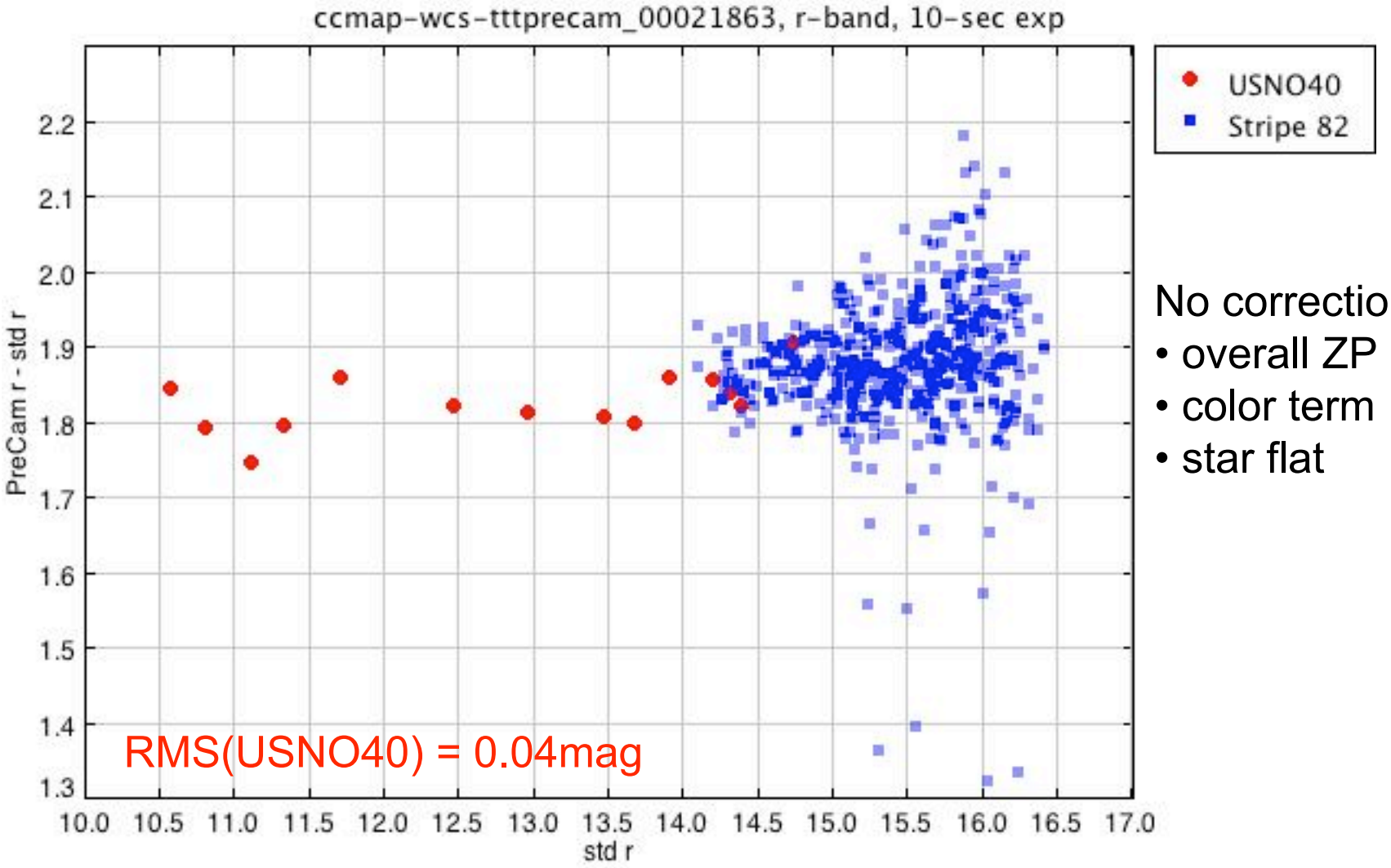
- After correcting, horizontal banding & streaking affect only about 6% of the processed images.



Credit: Sahar Allam

Results:
Initial Photometry for a Single Image

DARK ENERGY SURVEY



No corrections for:
- overall ZP
- color term
- star flat

From the Scientific Requirements Document

(sciReq-9.86, 10 June 2010)

(Update of a slide from Jim Annis)

DARK ENERGY SURVEY

R-10 For each of the *grizY* bandpasses of the wide-area survey, the fluctuations in the spatially varying systematic component of the magnitude error in the final co-added catalog must be smaller than 2% rms over scales from 0.05 to 4 degrees.

Internal (Relative) Calibration

$m_i = -2.5\log(f_{i1}/f_{i2}) + C$

R-11 The color zeropoints between the survey fiducial bandpasses (*g-r, r-i, i-z*) must be known to 0.5% rms. The *z-Y* color zeropoint shall be known to 1% rms.

Absolute Color Calibration

$m_i - m_z = -2.5\log(f_i/f_z) + zp_{iz}$

R-12 The i-band magnitude zeropoint relative to BD+17, and therefore the AB system, must be known to 0.5% rms.

Absolute Flux Calibration

$m_i = -2.5\log(f_i) + zp_i$

R-13 The system response curves (CCD + filter + lenses + mirror + atmosphere at 1.2 airmasses) must be known with sufficient precision that the synthesized *grizY* magnitudes of any astronomical object with a calibrated spectrum agree with the measured magnitudes to within 2%. When averaged over 100 calibrating objects randomly distributed over the focal plane, the residuals in magnitudes due to uncertain system response curves should be < 0.5% rms.

System Response

G-4 A goal of the survey is to achieve **R-10** at the enhanced level of 1% for the final co-added catalog.

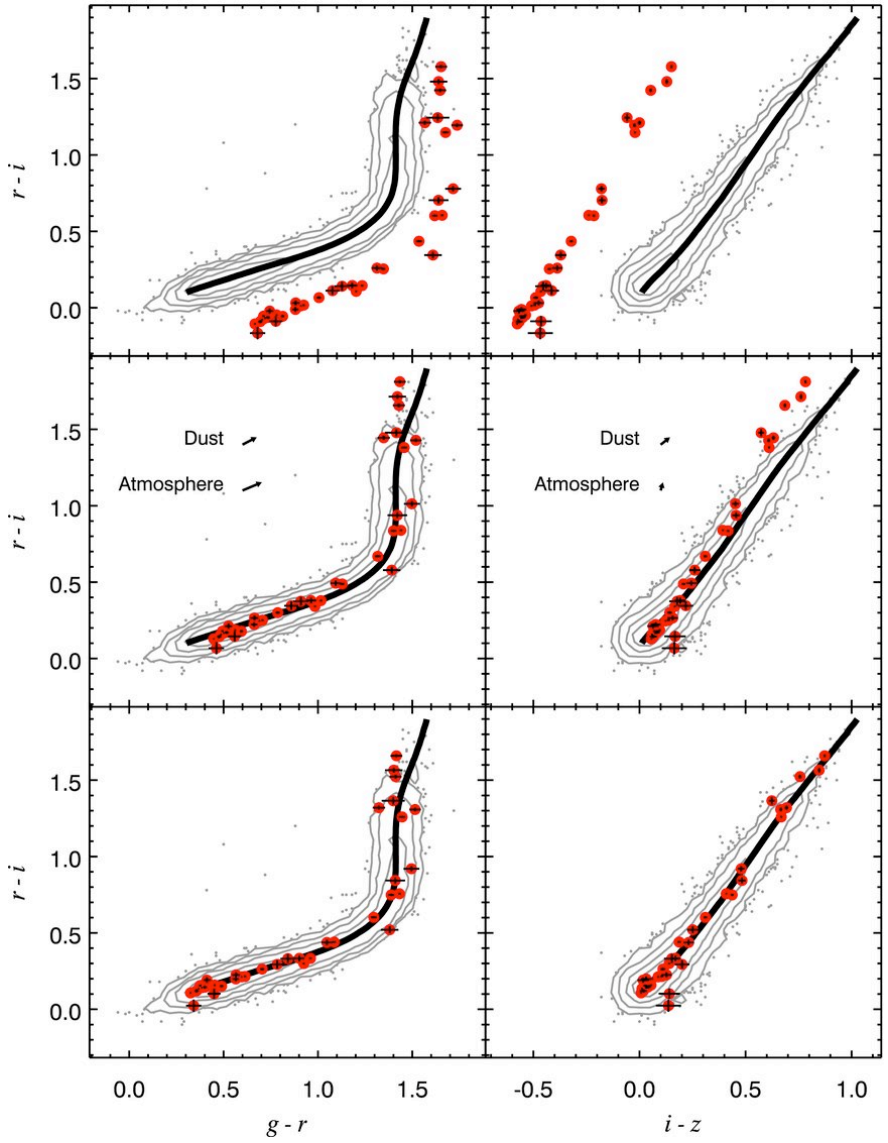
G-5 A goal of the survey is to achieve **R-10** over 160 degrees of Right Ascension and 30 degrees of Declination.

DARK ENERGY SURVEY

Additional:
For Rapid Calibration…

- The global relative and absolute calibrations will be performed seasonally (annually).

- For rapid calibrations between the seasonal running of the global calibration modules, one can make use of the stellar locus regression method of High et al. (2009), as implemented by Bob Armstrong of the DESDM team.



High et al. (2009)